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Diurnal variation in the relative intensity of 5577Å line from night airglow observed at Dumka (lat. 24°16′ N, long. 87°15′ E).

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A phenomenological analysis of the diurnal intensity variation of 5577Å line of night airglow has been made extending over a period of three years (1968-70) at Dumka (lat. 24° 16′N, long. 87° 15′E). It has been found that the night airglow is not a reasonably well-defined phenomenon, nor is it distributed homogeneously over a spherical shell. However, it has been found that usually there is a rise in intensity which attains a maximum and then gradually decays. This can most probably be explained on the basis of two opposite processes of excitation and de-excitation going on simultaneously in the atmosphere with various speeds (or efficiencies). The observed difference in nocturnal intensity variations from night to night would naturally mean corresponding difference in the rates of reaction.

INTRODUCTION

Measurement of the intensity of the night air-glow (for selected spectral regions or for the overall radiation) is important for many reasons. Thus, the measurement of the absolute intensity of a line radiation enables one to make an estimate of the corresponding number of emitted quanta, a knowledge of which is important in the theory of the excitation of the line. Again, simultaneous measurements of the intensity at different zenith distances provide data for estimating the height of the glow-emitting layer.

Photometric measurements show that the brightness of a selected spectral region of the night air-glow in the different parts of the sky is not uniform. There are limited regions or patches where the brightness is greater than the average.

Further, the brightness not only varies from day to day—some nights being of exceptional brilliance—but also, it varies progressively in course of a single night. Superposed on these fluctuations are slow variations, semi-annual and annual. It has also been found that the average brightness of the night air-glow waxes and wanes with the 11-year solar cycle. These temporal variations of the brightness of the air-glow may be classified as follows :

(1) Slow variation related to solar cycle.

(2) Annual and semi-annual variations.

(3) Diurnal variations.

(4) Irregular variations.

These variations are similar to those exhibited by the electron concentration of the ionospheric regions and there is strong evidence that the two upper atmospheric phenomena—ionization and night air-glow may be physically related to each other.

A large fraction of the research on the air-glow brightness is concerned with its variations with local time, *i.e.* with the longitude relative to the Sun. A daily maximum in the green-line intensity around local midnight was first reported by MClennan, *et al* (1928), and by Rayleigh (1929), and the possibility of a regular intensity variation has since been examined by many others. Till 1955, general consensus was that $(OI)_{32}$ green-line intensity was a more or less regular feature of the daily variation. The more recent work has disclosed a far more complex pattern, if indeed the daily variation can be said to follow a pattern at all. According to Barbier (1959) there is little tendency for the maximum to occur at any particular time, except possibly in the winter months. However, the tendency for I(5577) to pass through a maximum shortly after midnight had also been observed by Rodionov *et al* (1949) at Mount Elbrus, Georgia (43°N) and at other stations in mid-latitudes. Earlier, Karandikar (1934) had stated that there was a minimum near midnight at Poona, India (18°N) The possibility of the form of variation, being dependent on latitude was thus raised. The finding of Karandikar has subsequently been contradicted by Chiplonkar (1958) and his associates at Poona. Nevertheless the probability of latitude dependence has been established by now.

Elvey & Fransworth (1932) discovered the post- and pre-twilight effects. This is due to the fact that I(6300) is greatest in the evening and then rises slightly towards dawn. Barbier (1956) found that the post-twilight effect is pronounced throughout the year, whereas pre-twilight effect disappears during the summer and is marked only in the winter. This is in accord with the later results of Manring & Pettit (1957).

The Herzberg system of oxygen has been studied by Barbier (1953, 1954), who reports that the behaviour is rather erratic but that there is a tendency for the intensity to rise to a maximum.

Elvey (1943) made measurements in the infrared region, which refer to the Meinel hydroxyl system. They indicate that the emission sometimes decays slowly during the entire night and sometimes decays for the initial period and recovers. Armstrong (1956) has observed these and also other types of variations, which are irregular. Perhaps even more significant than the diurnal variations themselves is the fact that the intensities are maintained to a remarkable extent throughout the dark hours. As Chapman (1931, 1937) has pointed out, this is of great importance in connection with the problem of determining what is the source of energy of the night-glow.

2. Instrumentation

2.1. *Experimental Set-up.*

Observations were made by a home-made simple telescope using a RCA 931-A type photomultiplier tube as the sensing element. The telescope is on an altazimuth mounting so that it can be trained towards any part of the sky. For any fixed azimuth it can sweep from horizon to horizon and repeat the performance indefinitely. The azimuth-setting can be conveniently changed by 21°17′ at the end of each sweep and thus the whole sky can be covered. All the movements are controlled manually because it was found rather difficult to install a sophisticated automatic instrument in a remote suburban town like Dumka (Santhal Paraganas, Bihar).

The telescope proper consists of a rectangular metal box, having three separate compartments The top chamber accommodates an adjustable mounting for a large aperture lens (aperture 11 cm, $f = 13.5$ cm). The position of the lens can be finally adjusted by a telescopic sliding of two brass tubes, screw-fitted to one another.

The second partition wall is provided with a rectangular aperture having peripheral grooves to hold a Kodak deep green filter F. The principal axis of the lens L passes through the centre of the filter.

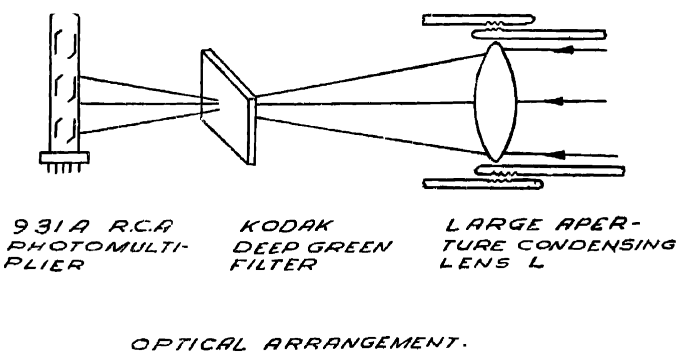


Fig. 2.1. Shows a schematic representation of the optical system.

The RCA 931A photo-multiplier tube is mounted horizontally below the filter F. The base of the photo-multiplier tube is mounted vertically on a perspex base, whose position can be accurately manipulated by means of spring and screw arrangements, from outside the metal box.

At a light level varying from 0 to 0.05 lumen, the collector current of a photo-multiplier tube changes from 0 to 2mA. When properly adjusted so that 5 secondaries appear for each incident electron, the current amplification would be, theoretically 5^9 or approximately 2 millions. The dark current is equivalent to that produced by about 10^{-9} lumen, in other words, is extremely small.

In order to reduce the dark current due to surface leakage, the telescope chamber is kept dry with the help of silica gel.

The galvanometer used was Leeds and Northrup type whose suspension fibre was changed to make it more sensitive (2.2×10^{-10} amp) than usual.

2.2. *Method of Measurement*

The telescope is mounted on the open terrace above the roof of the S. P. College building in Dumka (Bihar). Dumka (lat 24° 16′N; long 87° 15′E) is located in a hilly tract at a height of about 500ft. above sea level.

After preliminary levelling adjustments of the telescope, the H.T. unit is switched on. Usually 1100 volts is applied to the cathode of the photomultiplier tube. In order to minimise any current drift, the power pack is usually kept on during the entire period of observation. The dark current deflection θ_1 of the photomultiplier is obtained when the telescope lens is masked by a hood and the photomultiplier tube is encased in total darkness. The telescope is then conveniently rotated in its bearings so that the axis of the telescope points towards the Pole Star. Next, the mask of the telescope is removed and the lens L is suitably focussed. In order to get the maximum deflection of the galvanometer spot of light, the position of the photo-multiplier tube is also adjusted by means of suitable screw gadgets. This deflection θ_2 is carefully noted. The difference of these two deflections $(\theta_2-\theta_1)$ is proportional to the green component of the light of the night airglow coming from the north. Next, the telescope is rotated through an azimuthal angle of 180°. The value of $(\theta_2-\theta_1)$ now represents the intensity of the green component of the light of the night sky coming from the south in the geographical meridian, whose altitude is the same as that of the Pole Star.

It should be noted that since the instrument has not been calibrated against a standard source, the observations refer to relative integrated intensities only. However, the data yield meaningful interpretations of the nocturnal and seasonal variations in relative intensity of night airglow in the geographical meridian and also in different geographical directions.

During measurements the galvanometer with its accessories is kept in a small room at the top of the college building, while the telescope is mounted on an open terrace beneath the open canopy of the sky. The observations were made during periods of clear moonless nights only.

3, Experimental Results and Discussion

3.1. *Diurnal Variations of the Relative Intensity of 5577Å Line Emission Received from the Direction of Celestial Pole.*

The relative intensity of the green line at 5577Å coming from the direction of the Pole Star has been measured at Dumka for eighty five moonless nights between the period January 1968 to February 1970. Out of these, fifty-five are related to observations for complete nights, while the remaining observations are confined to half nights, either first half or the latter half, depending upon the visibility of the moon. The observations have been made at half-hourly intervals. The results have been graphically represented by plotting relative intensities against local 'night hours'.

Some nights have shown very small changes in relative intensity (Fig. 3.1A), whereas, some others have shown comparatively greater changes (Fig. 3.1B). Accordingly, nights may be termed as active or dull depending upon the relative intensity variations. Active nights have been observed mostly during the months of May and October, while dull nights occurred mostly during the months of January and February. A few nights in February '70 (Fig. 3.1C), may be considered as exceptional. On some nights, the changes in the relative intensity have been rather smooth (Figs. 3.1A, 3.1B) while in a few other cases, the changes have been rapidly fluctuating (Fig. 3.1D).

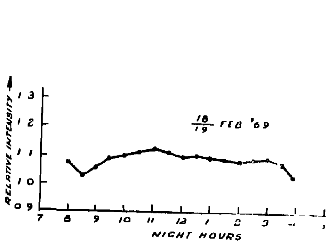


Fig. 3.1A

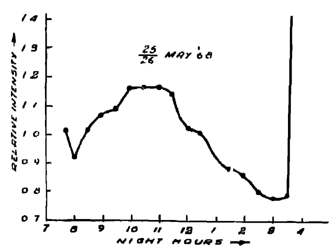


Fig. 3.1B

In general, two maxima in the relative intensity variations have been observed during a complete night. In most cases, the first maximum occurs before midnight and is quite prominent. The second maximum which occurs after midnight is rather less pronounced (Fig. 3.1E). However, in a few stray cases the second maximum has been found to be more prominent than the first one (Fig. 3.1F).

Fig 3.1C

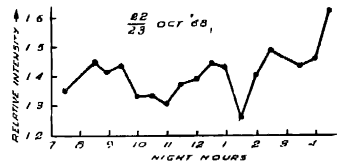


Fig. 3.1D

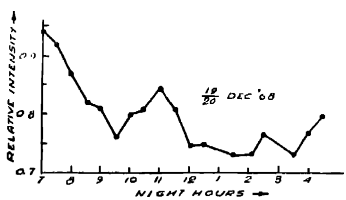


Fig. 3.1E

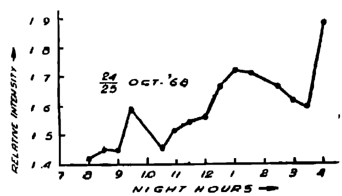


Fig. 3.1F

In December, occurrence of the first maximum has been found to be in the neighbourhood of 9.30P.M. which timing progressively shifts towards 11.00 P M. in the month of May and returns to 10.00 P.M in October. On 21/22 May '68, (Fig. 3.1G) the maxima in relative intensity variations appeared rather earlier, the first at 9.00 P.M. and the second at 12.00 P.M., the latter being more prominent than the first. On a few nights, the first maximum in relative intensity variations becomes suppressed and the second one becomes quite sharp (Fig 3.1H). The second maximum in relative intensity variations has been seen around 1.00 A.M. or 2.30 A.M., during the months of January, February, March, October and December. In May the second maxima in relative intensity variations occur around 1.30 A.M. and rarely around 2.30 A.M. Thus, in general, relative intensity changes during a night reveal one maximum after midnight. In some cases, however, two maxima appeared after midnight. This happens mostly during the months of January, February, March, October and December (Fig. 3.1I). This feature of two maxima, in relative intensity variations, occurring after midnight has been shown on 4% of the nights for which observations have been collected. In extreme cases, during some nights only one minimum appeared around midnight, when the maxima are completely supressed (Fig. 3.1J).

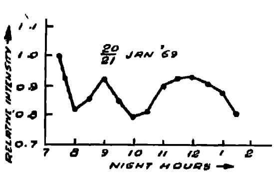


Fig. 3.1G

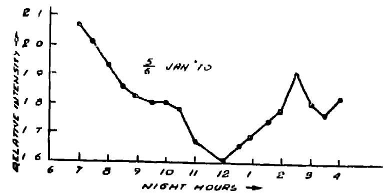
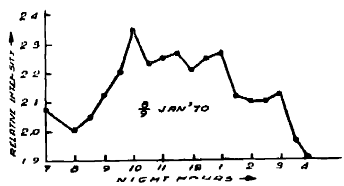
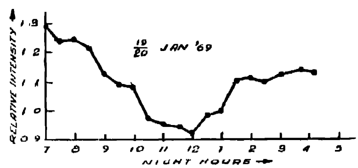


Fig. 3.1H



Figs. 3.1I



Figs. 3.1J

3 2. *Emission Received from the Southern Direction in the Geographical Meridian having an Altitude Equivalent to that of the Pole Star*

Relative intensity of the green light 5577 Å coming from the above direction has been measured for seventy two clear moonless nights. Most of the observations have been taken for complete nights. The results have been represented graphically where the relative intensity has been plotted against local night hours. Those graphs reveal generally two maxima. The first maximum usually occurs before midnight while the second maximum appears after midnight. The average time of occurrence of maxima for different months has been shown in Table 1.

Table 1

Month	Time of Occurrence		Remark
	1st Maximum	2nd Maximum	
January	9.00 P.M.	1.00 A M.	
February	10.00 P,M.	2.30 A.M.	
March	9.00 P.M.	1.00 A.M.	
May	12.00 P.M.	—	Only mid-night maximum
December	8.30 P.M.	3.00 A.M.	

The only maximum in the month of May is seen around mid-night (Fig. 3.2A.) Pre-midnight maximum in relative intensity variations has also been seen on 22/23 May '68 (Fig. 3.2B). When two maxima are seen during a night in the month of May, the second maximum is broader than the first maximum. However, the relative intensity variations during some nights cannot be reconciled with the above generalization. For example, the relative intensity variation for complete night on 20/21 January '69 (Fig. 3.2C) shows only one maximum, while that on 14/15 January '69 (Fig. 3 2D) more than two maxima. Again, the curve

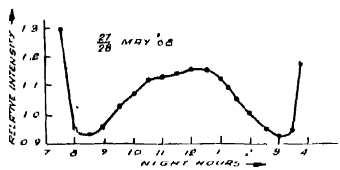


Fig 3.2A

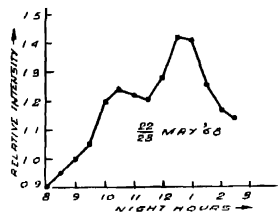


Fig 3 2B

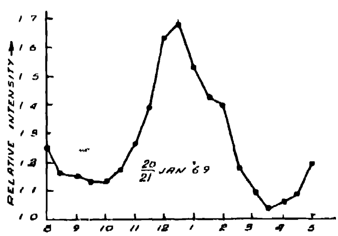


Fig. 3.2C

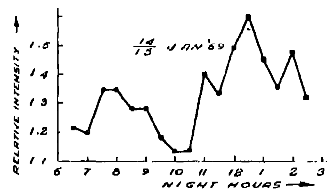


Fig. 3.2D

for 3/4 February '70 (Fig. 3.2E) shows a pre-midnight minimum. The relative intensity variation on 25/26 March '69 (Fig. 3.2F) shows post midnight maximum which is larger than the premidnight maximum. On the other hand, the pre-midnight maximum is very much suppressed on 29/30 March '68 (Fig. 3.2G). On 6/7 December '69 (Fig. 3.2H) it is found that the first maximum in relative intensity variation occurs rather late, *i.e.*, at 10.30 P.M. when the normal time of occurrence of the first maximum should have been round about 8.30 P.M. Similarly Fig. 3.2I for 10/11 December '69 exhibits an exception because a sharp minimum in the relative intensity variation is seen to occur at 1.00 A.M., when normally it should have occurred between 11.30 P.M. and 12.30 P.M. The relative intensity variations are usually smooth, accompanied by large amplitudes except for some rare nights like 14/15 January' 69 (Fig. 3.2D), when some unaccounted for fluctuations intervene.

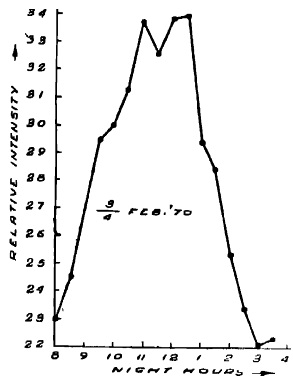


Fig. 3.2E

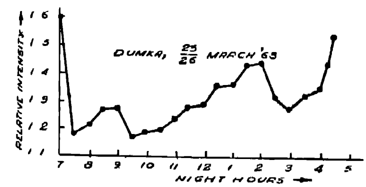


Fig. 3.2F

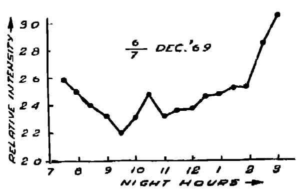


Fig. 3.2H

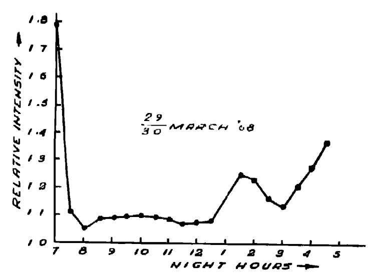


Fig. 3.2G

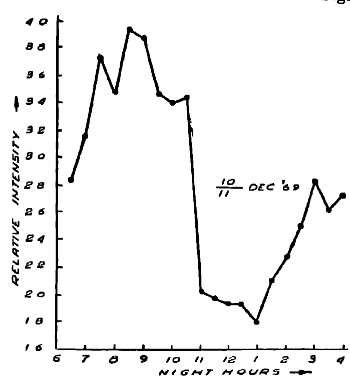


Fig. 3.2I

It has been found that during the months of February and March relative intensity is higher during the first half of the night as compared to the second half. Nor is it evenly distributed between the two halves of nights during the month of December. As a matter of fact, the relative intensity in the first half is higher than that during the second half for some nights and vice-versa for some others in the month of December. Moreover, the month of May does not show any clear-cut distinction between the relative intensities during the two halves of nights. In January '68 the relative intensity has been seen to be higher during the first half of nights as compared to the second half. However, quite opposite results have been obtained for January '69 and January '70.

3.3. *Emission Received from the Direction of Zenith.*

The relative intensity of the green line at 5577Å of the night airglow coming from the direction of the zenith has been measured on eighty four clear moonless nights. Graphs of the relative intensities have been plotted against local night-hours. Out of eightyfour nights the majority of the observations are for complete nights, while the remaining observations are for the first or second half of nights depending upon the time of visibility of the moon.

During the months of January, February and March the relative intensity has been found to be greater in the first half of night and lower in the second half. In the month of April an almost balanced distribution of the relative intensity between the two halves of nights is observed. During the month of May and October the relative intensity has been higher for the second half of night in comparison to the first half of night, 29/30 May '69 (Fig. 3.3A) being an exception to the above generalization. In the month of December a balanced distribution. relative intensity of the 5577Å emission exists between the two halves of nights, while 9/10 December '69 (Figs. 3.3B) seems to be an exception to the above generalization. The variations in the relative intensity are generally

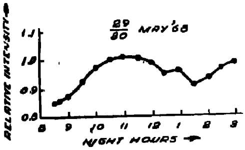


Fig. 3.3A

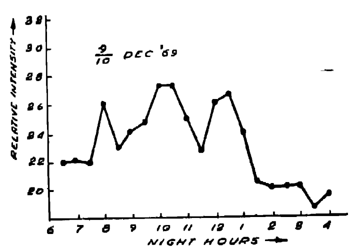


Fig. 3.3B

regular as on 15/16 March '69. (Figs. 3.3C). A few nights like 15/16 February '69, 13/14 March '69 (Figs. 3.3D, 3.3E) show fluctuations in the relative intensity variations.

During complete night observations the variations in the relative intensity have shown two maxima, one in the first half of night and the second in the latter half. The time of occurrence of the first maximum and second maximum has varied erratically from month to month. The first maximum has been found to occur usually between 8.30 P.M. and 10.30 P.M. and the second maximum mostly between 12.00 P,M. and 2.30 A M. The averge times of occurrence of the maxima during nights in different months have been shown in Table 2.

Table 2

Month		Time of Occurrence 1st Maximum	2nd Maximum	Remarks
January	'68	8.30 P.M.	1.00 A.M.	
,,	'69	9.30 P.M.	1.30 A.M.	
,,	'70	10.00 P.M.	2.30 A.M.	
February	'68	8.30 P.M.	2.00 A.M.	
,,	'69	11.30 P.M.	3.30 A M.	
,,	'70	8.30 P.M.	1 30 A.M.	1st maximum suppressed, 2nd maximum sharp.
March		10.00 P,M.	12.00 P.M. 2.30 A.M.	
April		9.00 P.M.	12.00 P.M. 2.00 A.M.	
May		10.30 P.M.	1.00 A.M.	(rare)
October		9.00 P,M.	1.30 A.M.	
November		9.30 P.M.	—	No observation made for the 2nd half of night
December		Usually mid-night maximum.		

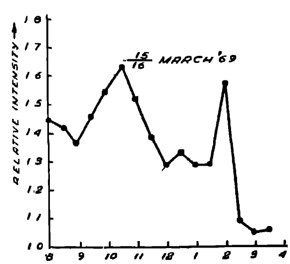


Fig. 3.3C

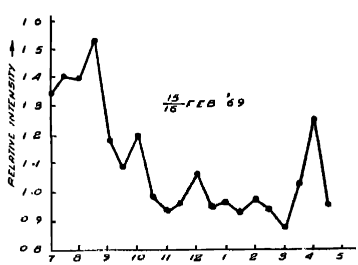


Fig. 3.3D

17/18 February' 69 shows a sharp second maximum at 3.30 A.M. in the relative intensity variations (Fig. 3.3F). The post midnight maximum in the relative intensity variations during the month of January has been seen very rarely and when it is seen, it is smaller than other maxima (Fig. 3.3G) for 8/9 January' 70. The second maximum of the relative intensity variations during the month of Februaıy is seen to be very sharp and the first maximum is suppressed (Fig. 3.3F). The changes in the relative intensity on 29 February/1March '68 (Fig. 3.3H) are very small and the first maximum is almost absent and a very small second

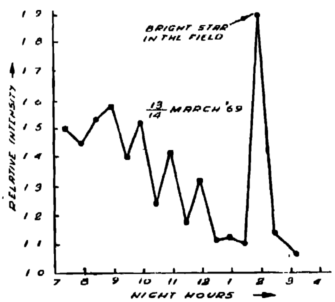


Fig. 3.3E

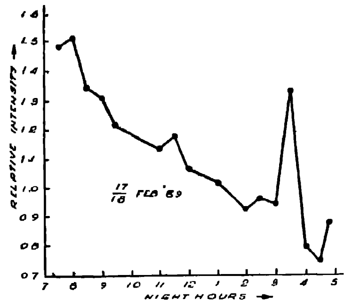


Fig. 3.3F

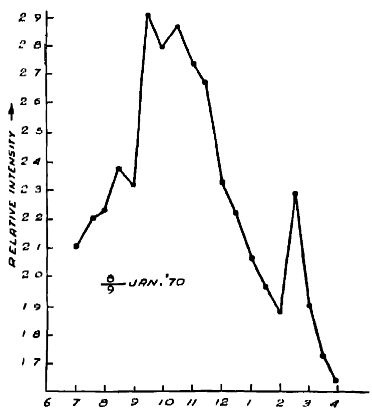


Fig 3.3G

maximum is seen in the post mid-night period. Measurements on 4/5 January '70 (Fig 3 3I) show more than one maximum in the relative intensity variation before midnight. In the month of March three maxima in the relative intensity variations during a complete night occurred of which the second one is not very sharp (Fig. 3.3C). Only one maximum has been observed during the month of May but on rare occasions two maxima during a night have also been recorded. The two maxima may lie in the first and second half of night, respectively, as seen on 23/24 May '68 (Fig. 3.3J). Though the month of December has shown usually one midnight maximum, sometimes two or three maxima have been found as on 19/20 December '69 (Fig. 3 3K). The case of two or three maxima in the relative intensity variations during a complete night of observation is an exception to the generalization that only one midnight maximum is seen in the month of December

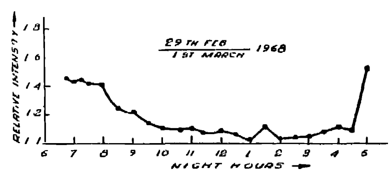


Fig. 3 3H

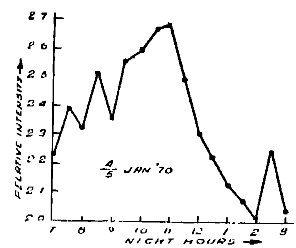


Fig 3.3I

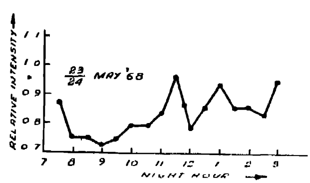


Fig. 3.3J

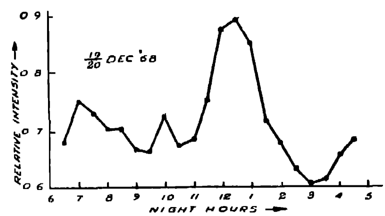


Fig. 3.3K

3.4. *S/N Ratio Emission Received from Southern and Northern Directions in Geographical Meridian at an Altitude Equivalent to that of Celestial Pole.*

The value of the *S/N* ratio has been calculated for a number of nights by measuring the relative intensity of the 5577Å line from the direction of the north pole and from the southern direction in the geographical meridian at an altitude equivalent to that of the Pole Star. The study of the *S/N* ratio has been particularly chosen in as much as it is independent of calibration constant of the instrument. Similarly the correction for scattering and absorption is eliminated by assuming that those factors are more or less identical for those two directions.

The results have been represented graphically by plotting the value of S/N ratios against local night hours.

Generally two maxima in the value of S/N ratio have been observed during a complete night. During the month of January, March, November and December the first maxm. occurs near 9.00 P.M But in the month of May the first maxm. in the ratio occurs near 10 00 P.M. During the month of February the first maxm. in the values of S/N ratio has been found to be near 9.00 P.M. in 1968. The time period of maxm. shifted to near 1.30 P.M. and 11.00 P.M., respectively, for the same month in 1969 and 1970. The second maxm. has been usually seen to occur in the neighbourhood of 1.00 A.M. except for 17/18 February '69 (Fig. 3.4A) and 7/8 December '69 (Fig. 3.4B)when it has occurred near 2.30 A.M. and 4.30 A.M. respectively. During the month of January, the S/N ratio shows both the maxima to appear a bit earlier in comparison with other months. The second maxm. is now seen to be larger than the first maxm. (Figs. 3 4C) on 19/20 Jan'68. However, on 31 Jan./1st Feb. '68 (Fig. 3.4D) the first maxm. in the value of S/N ratio has occurred at 11.30 P.M.

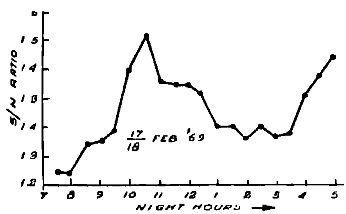


Fig. 3.4A

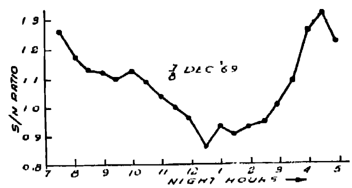


Fig. 3.4B

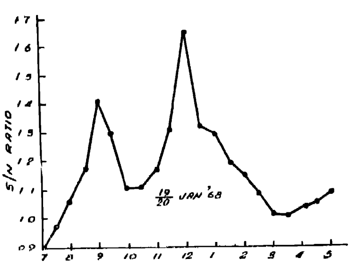


Fig. 3.4C

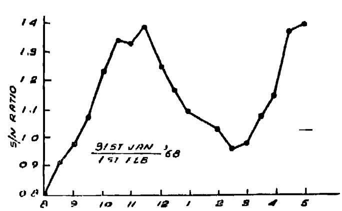


Fig. 3.4D

which is rather late in comparison to its scheduled time of 9.00 P,M. Measurement on 3/4 February'70 (Fig. 3.4E) has shown that the first maxm. in the value of the S/N ratio arrives at 9.30 P.M., which is much earlier than its time schedule at 11.00 P.M. Similarly a sharp maxm. has been seen at 10.30 P.M. on 6/7 December '69 (Fig. 3.4F) which is rather late in comparison with its normal timing at 9.00 P.M. On some nights a minimum has been observed at a time when the S/N ratio should have shown a maxm. (3.4G). The value of S/N ratio on 3/4 February '70 (Fig. 3.4E) has shown two maxima during the first half of the night while 5/6 January '70 (Fig. 2.4H) has shown two maxima in the second half of the night, of which the first maxm. is more pronounced. On a few nights only one post-midnight maxm. has been seen in the value of S/N ratio (Fig. 3.4I). The value of S/N ratio has been found to be higher in the first half

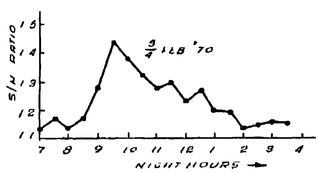


Fig. 3.4E

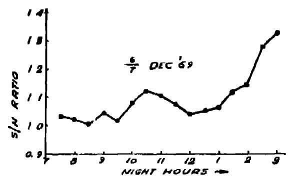


Fig. 3.4F

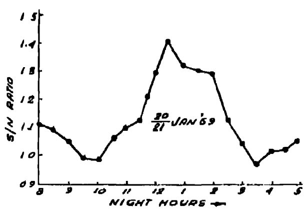


Fig. 3.4G

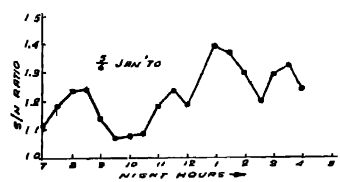
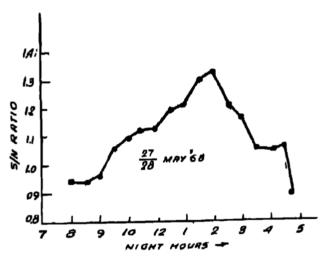


Fig. 3.4H



Figs. 3.4I

of night in the month of January except January' 68. The month of February has shown a higher value in the S/N ratio in the second half of night. In the months of May and December no. well defined distribution in the value of S/N ratio between the two halves of nights was not observed. The diurnal variations in the S/N ratio are usually smooth except for a very few nights like 10/11 December '69

3.5. *Average Relative Intensity of Night Airglow.*

The average intensity has been calculated by taking mean of the relative intensities of the 5577Å line emission coming from the directions of (i) the celestial pole, (ii) the zenith, (iii) the south in the geographical meridian having an altitude equal to that of the celestial pole. The results have been represented graphically by plotting relative intensities against local night hours. Generally two maxima are seen in the relative intensity variations during a complete night. The first maximum occurs before midnight and second after midnight. Some nights have shown the first maximum to be bigger than the second (Fig. 3.5A) as on 16/17 Feb. '69 while some others have shown the second maximum to be large in comparison to the first (Fig. 3.5B) on 20/21 Jan '69. Moreover some nights have shown both the maxima in the relative intensity variations to be well pronounced (Fig. 3.5C) on 13/14 March '69. On some nights as on 28/29 March '68 the activity is very dull (Fig. 3.5D) while some other nights (Fig. 3.5E, 6/7 Dec '69) record

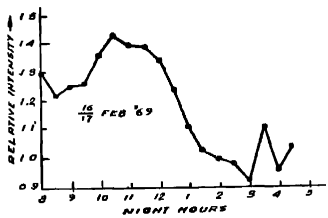


Fig. 3.5A

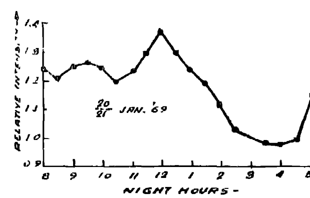


Fig. 3.5B

quite high activity. The curve for 28/29 March '68 (Fig. 3.5D) does not show even a small maximum during a complete night. Indeed, the relative intensity has remained virtually constant for greater part of the night. The nights in the month of May have generally shown larger changes in relative intensity as revealed in Fig. 3.5F for 23/24 May'68 while Fig. 3.5G for 26/27 May '68 shows very small changes in relative intensity. On some nights as on 5/6 Jan '70 the relative intensity undergoes large fluctuations (Figs. 3.5H), whereas the remaining nights show only medium variations. Furthermore, some nights have shown more than two maxima in relative intensity variations during a complete night as on 9/10 Dec. '69 and the maxima are quite pronounced (Fig. 3.5I). Fig. 3.5J for 8/9 February '70 shows typical variations in the relative intensity which appears to decrease stepwise throughout the whole night. During the month of February

'68 and February '69 the activity has been low while on some nights in February '70 the activity has been seen to be relatively high (Figs. 3.5K).

Normally, the time of the first maximum has been found to appear between 9.30 P.M. and 10.30 P.M. and second maximum between 12.30 A.M. and 2.30A M. During the month of May, the relative intensity variations have shown only one maximum centred around midnight while, during one exceptional night of 24/25 May '68 (Fig. 3.5L) three maxima have been observed The minimum in the relative intensity variations has generally fallen between 11 00 P.M. and 1.00 A.M. except for the month of May which has shown a midnight maximum and the relative intensity falls on both sides of the maximum (Fig. 3.5M). On the other hand the relative intensity variations on 9/10 December (Fig. 3.5I) indicates smaller midnight maximum.

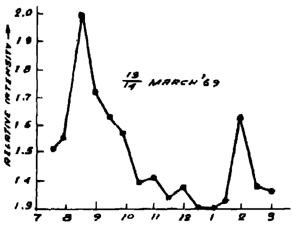


Fig. 3.5C

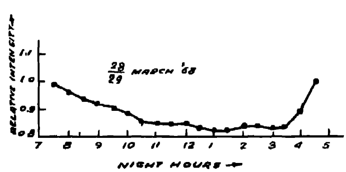


Fig. 3.5D

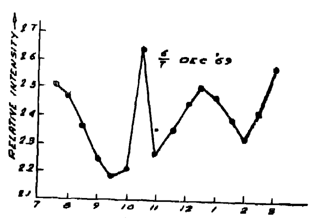


Fig. 3.5E

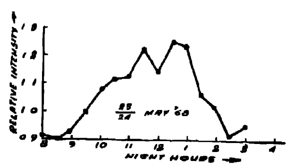


Fig. 3.5F

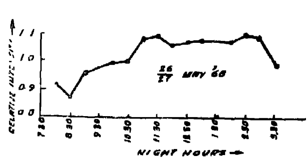


Fig. 3.5G

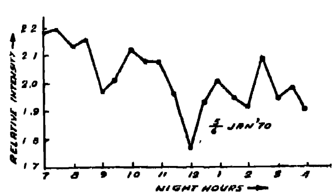


Fig. 3.5H

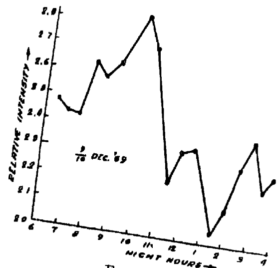


Fig 3.5I

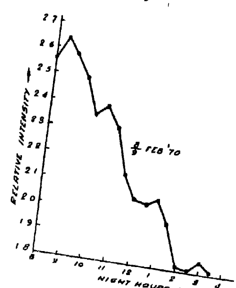


Fig 3.5J

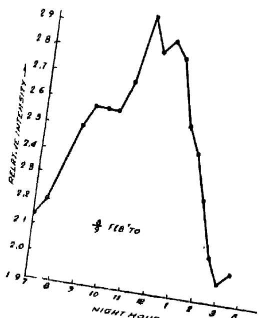


Fig. 3.5K

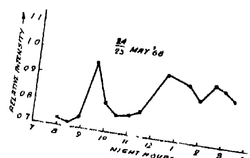


Fig. 3.5L

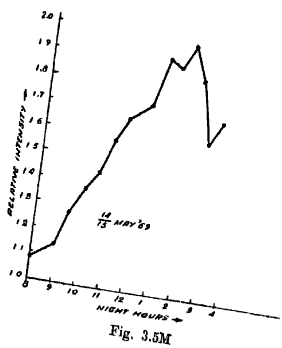


Fig. 3.5M

3 6. *Discussion*

The mean diurnal variations are usually quite different from the individual night to night variations. The times of occurrence of the first premidnight maximum and the postmidnight maximum change during different nights during the same month or in different months. This confirms the observations of Roach *et al* (1951) at Cactus Peak. The diurnal variations in sub-sections 3.1 and 3.5, which have shown greater similarities are classified in Group A. The diurnal variations described in sub-sections 3.2 and 3 4 are shown in Group B and those in sub-section 3 3 are in Group C

Group A

The following points may be particularly noted :

i) Usually two maxima have been recorded during a complete night of observations.

ii) The first maximum occurs before midnight between 9.30 P.M. and 11.00 P.M. and the second maximum occurs between 12 30 P.M. and 3.00 A.M. The first maximum is usually more pronounced than the second This result is analogous to that of Chiplonkar *et al* (1958) and V. V. Agashe (1968) for their work at Poona (India) at a latitude of 18.05°N.

iii) The time of occurrence of the first maximum progressively shifts as the winter months merge towards the summer months. This raises the possibility of the dependence of the first maximum on the longitude of the sun. This hypothesis seems to support the hypothesis of Chiplonkar *et al* (1958).

iv) During some nights the variations in the relative intesity are quite smooth while during some other nights the variations have been found to be rapidly fluctuating.

v) Generally the first premidnight maximum is more pronounced than the second postmidnight maximum. However, on a few nights the first maximum has been found to be less pronounced in comparison to the second maximum. On a few rare nights both the maxima have been found to be well pronounced

vi) A few rare nights have revealed rather dull activity, the relative intensity remaining almost constant during the whole night. Again some other nights have shown fairly high activity.

On the otherhand W. R. Steiger (1967) for his observations at Haleakala, Hawaii (Lat. 20°N) has reported the occurrence of one maximum during a complete night of observations. He does not report more than one maximum. This may be due to the difference in the latitude between different places of observation Alternatively, it may be due to the difference in the longitudes of the various places of observation as suggested by Silverman (1965).

Group B

Diurnal intensity variations classified in sub-sections 3.2 and 3.4 have also shown much similarity. The results of the above variations may be listed as follows :

i) The variations have shown quite smooth changes in the relative intensity.

ii) The variations have shown usually two maxima during a complete night of observations This first premidnight maximum in both the cases has been found to occur in the neighbourhood of 9.00 P.M. The second maximum has been found to occur between 1.00 A.M. and 2.30 A.M In the case of S/N ratio the second maximum has been seen to be nearer to 1.00 A.M.

iii) In both the above cases, the time of occurrence of the first premidnight maximum has shown a progressive shift from winter months to summer months. Considering the S/N ratio the first maximum shifts from 9.00 P.M. in winter months to 10 00 P M. in the month of May. Regarding the intensity as described in sub-section 3.2 (coming from the direction of south in geographical meridian at an altitude equal to that of the Pole Star), the above shift is greater and reaches midnight in the month of May.

iv) The first maximum in the variations in sub-section 3.2 occurs a bit earlier than the corresponding variations in sub-section 3.1. Moreover, the intensity of the light, coming from the southern direction (sub-section 3 2) is greater than that coming from the direction of the celestial pole (sub-section 3 1). The amplitude of intensity variations in the light coming from the southern direction (sub-section 3 2) is greater than that coming from the northern direction (sub-section 3 1). It is reasonable to believe, that higher values of relative intensity in sub-section 3.2 in comparison to the value of relative intensity in sub-section 3.1 might have brought about the changes in the diurnal variatons in sub-sections 3.2 and 3 4 closer to each other

Group C

The variations in the relative intensity of the green light coming from the direction of the zenith (sub-section 3.3) has not shown well defined changes. The times of occurrence of the first premidnight maximum and of postmidnight maximum vary erratically from month to month. The time of occurrence of the first maximum does not show any progressive shift from winter to summer months, (as the variations in the sub-sections 3.1, 3.2, 3.5 have shown). Similar report of no regular changes for the zenith intensity has been reported by Chiplonkar *et al* (1958) and Agashe (1968), for their work at Poona Roach (1954) and Barbier *et al* (1954) working near mid latitudes, have also reported that the emission rate at zenith is an irregular feature and have shown the time of maximum to be 2 5 hours around midnight. At Dumka, the time of occurrence of the first maximum (in the relative intensity variations) has been found to come up to about 3½ hours before midnight. The second maximum is usually suppressed but when spotted, its time of occurrence lies between 12 00 P M. to 2.30 A M Roach *et al* (1958) have reported that some times more than one maximum have been seen. At Dumka usually two or three maxima have been found during a complete night. This supports their conclusion that the detailed feature of the excitation pattern varies from place to place and moreover the excitation pattern seems to possess a motion. Steiger & Smith (1968) have reported (on statistical average) a midnight maximum for their work at Haleakala (Lat 20° 7′N) and Kittypeak (Lat. 35°N) They have made corrections for the astronomical light and extinction etc. But they have also reported several types of diurnal variations having different level of intensities during the same month. There have been also sudden changes in the intensity levels during the same month at Dumka and some of them have been correlated with solar flares (sub-sec. 3.12) However, in addition to the above, some nights have shown higher relative intensities in comparison with some other nights during the same month. There have been different types of diurnal variations as detailed in sub-sec. 3 3. Thus the results for zenith intensity agrees, with those reported by Steiger & Smith (1968) Large and small amplitude variation have been reported by Davis & Smith (1965) At Dumka also, one finds large amplitude variations in relative intensity during the month of May and October and small amplitude variations during the months of January and February with a few exceptions. It may perhaps be noted that the variations itemised in sub-sections 3 1, 3.2 and 3.5 have shown a maximum near midnight during the month of May, while the relative intensity towards the zenith has shown a midnight maximum in the month of December.

3.7. *Emission Received from an Altitude Equal to that of Pole Star in Different Azimuthal Planes*

For the study of this variation, observations have been taken on a few nights with the telescope fixed at an altitude equivalent to that of the Pole Star, which is subsequently rotated to different azimuthal planes at intervals of about 21°. The perusal of the results presented in graphs with relative intensities plotted against different local hours of the nights show the following changes:

A well pronounced maximum is always situated at a declination of 105°W to 120°W (Fig. 3.7A) of the geographical meridian. A smaller maximum is seen at a declination of 42°E to 85°E (Figs 3.7A, 3.7B) The smaller maximum shifts to a declination of about 127°E at 2.00 A M (Fig. 3.7C) and then returns to the declination of 42°E at 4.00 A.M (Fig 3.7D). In addition, a smaller increase in relative intensity is seen in the north at 10 00 P.M. (Fig. 3.7E) and 11.00 P M. (Fig 3.7F). This increase is not found afterwards. This seems to be correlated with the first maximum near 10 00 P.M for the green component of the light of the night sky coming from the direction of the north pole On some nights, one, two or more maxima are seen in addition to the usual maximum mentioned above (Figs. 3 7F, 3.7G). This first maximum being at a declination of 105°W to 126°W is always much more pronounced than any other maximum which appears in the first half of the night, i e. up to 12 00 P.M. After 12 00 P M the second maximum almost equals the first maxium (Figs, 3.7D, 3.7H).

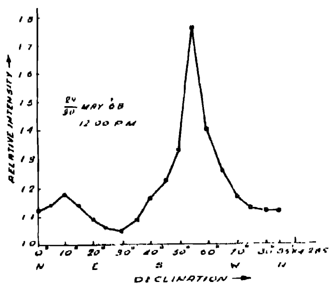


Fig 3.7A

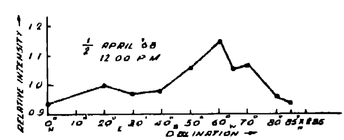


Fig 3 7B

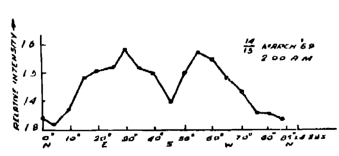


Fig. 3.7C

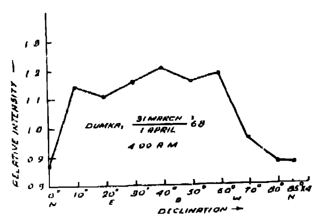


Fig. 3.7D

The minima are seen mostly in the northern direction and at a declination of 127°E to 170°E (Figs. 3.7A, 3.7H), The minimum in the north (*i.e.* the first minimum) is always deeper than the other one. The first minimum shifts to a declination of 42°E at 10 00 P M. and to 21°E at 11.00 P.M. (Figs. 3.7E, 3.7F). This is the period of first sharp maximum in the green component of the light of the night sky coming from the direction of the north pole. This shift of the minimum at 10. P. . nd 11.00 P.M. and again its subsequent return to the direction of the geographical north is well correlated to the variation of the green component of the nightsky light coming from the direction of north pole. A small maximum in the geographical north has also been seen at this period of the night (Figs. 3.7E, 3.7F). The second minimum lies between the declination 84°E to 170°W. It is nearer to the declination of 127°E upto 12.00 P.M. (Fig. 3.7B) which attains a declination of 170°W (Fig. 3.7H) at 2.00 A.M. and falls back to 84°E at 4.00 A.M

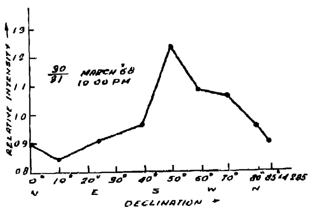


Fig. 3.7E

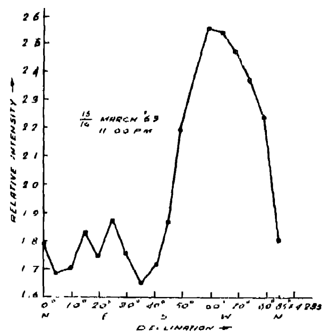


Fig 3.7F

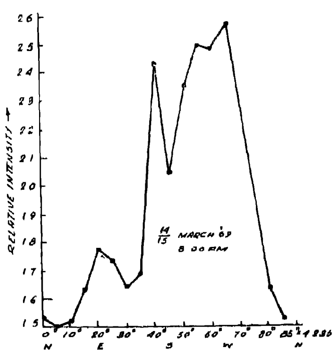


Fig. 3.7G

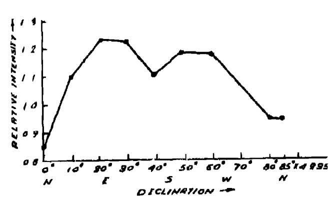


Fig. 3.7H

Thus one finds that the intensity is maximum near the S-W direction and minimum towards the celestial pole in the northern side and in the S-E direction in the southern side.

3.8 *Emission Received at Different Altitudes (Zenith Angles) in the Geographical Meridian.*

During some nights measurements for relative intensity of the 5577 Å line of the night airglow have been made at different altitudes in the geographical meridian. The results have been graphically plotted with relative intensities against altitudes, for different hours of nights. The relative intensity in the south has always been found to be greater than that on the northern direction except on rare occasions like the one on 31March-1st April '68 (Fig 3.8J).

The positions of maxima and minima in relative intensity *vs* altitude curves at different hours of the night for the month of Februry have been represented in the following table.

Table 3

Month	Time	Position of maxima		Position of minima	
		Northern side	Southern side	Northern side	Southern side
	9 30	80°N	40°S	0°(no clear intermediate min)	0°(with 17/18 Feb. as exception)
	12 00	20°N	30°S, 80°S	60°N	80°S
February	2 00	20°N, 50°N	30°S, 70°S	60°N	60°S
	4 00	30°N, 90° (Zenith)	30°S, 90° (Zenith)	50°N	80°S

This table shows that on both sides of the vertical there is one maximum at 9.30 P.M., while there are two maxima at 12.0 P.M. and 2.00 A.M respectively. It is found that the second maximum at higher altitudes in the northern and southern sides merge into one to produce a maximum in the zenith direction. Above table shows that the position of maximum in the north firstly moves a little towards the horizon and afterwards towards the zenith. In the southern side, the maximum at 9.30 shifts a little towards the horizon and remains there for the rest of the night while a second maximum appears at higher altitude near the zenith which reaches the zenith at 4.00 A.M. As the night advances, the position of the maximum shifts a little towards the horizon on the northern side moves towards the zenith on the southern side (Figs. 3.8A, 3.8B, 3.8C and 3.8D).

It is found that most regular relative intensity variations (with altitude in the geographical meridian) take place during the month of March. A clear maximum has been found at 20°N, 20°S with an occasional slight increase in the relative intensity near 80°S, 80°N or 90° zenith. The maximum on the southern side has been always more pronounced than that on the northern side with the exception of the maximum in relative intensity on 31 March-1st April '69 (Fig. 3.8J) at 2.00 A.M. when the maximum in the north is slightly greater than the maximum in the south. The position of minimum has remained more confined near zenith with occasional shifts to 60°N and 60°S (Figs. 3.8E, 3.8F, 3.8G, 3.8H, 3.8I and 3.8J).

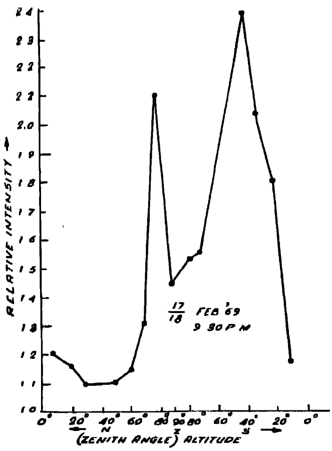


Fig. 3.8A

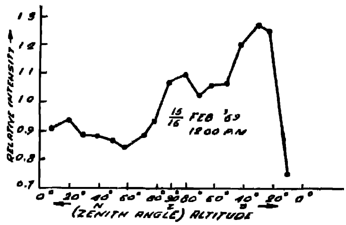


Fig. 3.8B

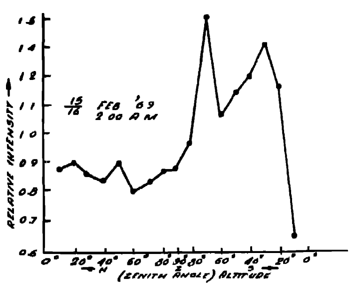


Fig. 3.8C

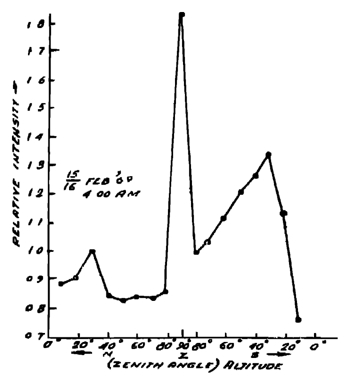


Fig. 3.8D

The changes in the relative intensity as function of altitudes have been quite regular during the month of April. The position of maxima has been located at 20°N, (20°S to 60°S) and the position of minimum near 80°N (Figs. 3.8K, 3.8L, 3.8M, 3.8N).

The variations during the month of May have shown the location of maximum on the northern side between (20°–30°)N and on the southern side between (30°-50°)S. On the northern side position of maximum is higher towards the zenith upto 12 00 P M. and then falls to a relatively lower altitude at 3 00 A M The position of maximum on the southern side steadily shifts towards the zenith. The position of minimum in the relative intensity is found near zenith at 9.30 P.M. and 12 00 P M. and moves away from the zenith at 3.00 A M. (Figs 3 8O, 3.8P, 3.8Q).

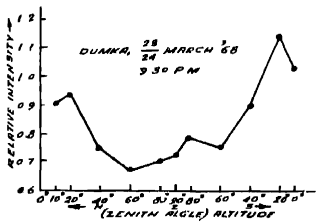


Fig. 3.8E

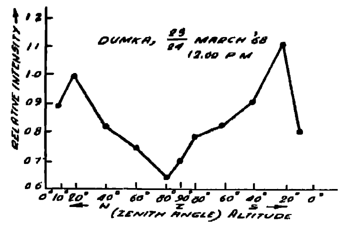


Fig 3.8F

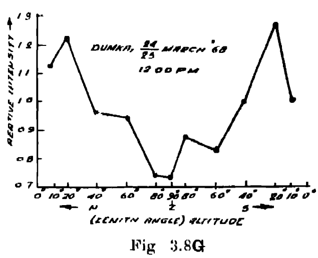


Fig 3.8G

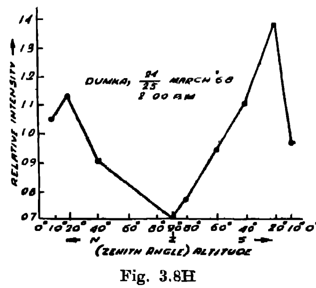


Fig. 3.8H

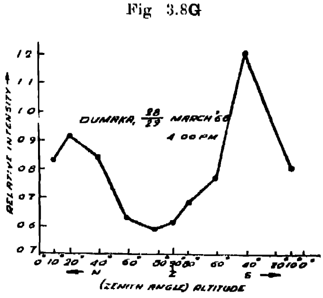


Fig 3 8I

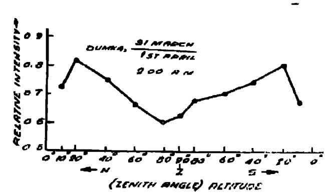


Fig. 3.8J

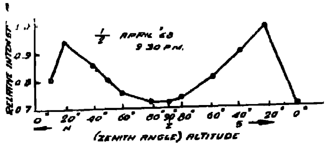


Fig 3 8K

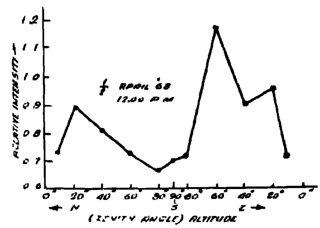
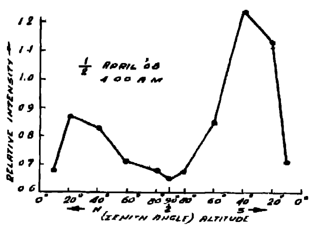


Fig. 3.8L



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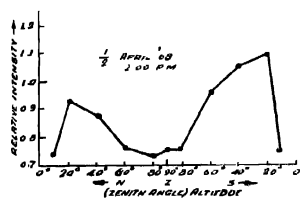

Fig. 3 8N

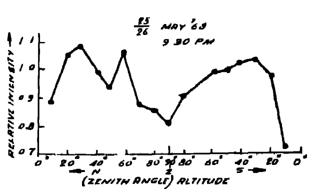

Fig. 3.8O

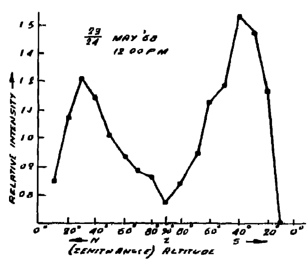

Fig. 3.8P

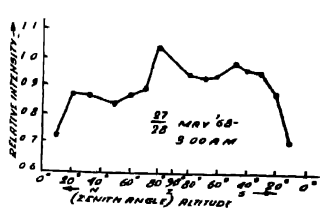

Fig. 3.8Q

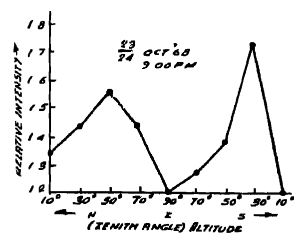

Fig. 3.8R

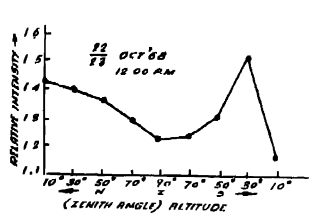

Fig. 3.8S

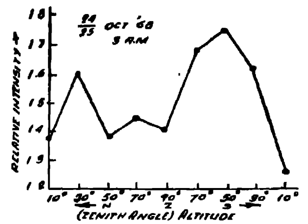

Fig. 3.8T

The changes in the relative intensity with altitude during the month of October have shown a minimum near the zenith. The position of the maximum in the northern side has changed from 50°N at 9.00 P.M. to 10°N at 12 00 P.M. and to 30°N at 3.00 A.M. The position of maximum in the southern side has shifted from 30°S in the first half of night to 50°S in the second half of night (Figs. 3 8R, 3 8S, 3 8T).

3.9. *Discussion*

(1) For the diurnal variations in relative intensity of 5577Å emissions coming from different azimuthal planes from an altitude equivalent to that of the pole star, one finds a maximum in the S-W direction and two minima (i) one in the northern direction and (ii) the other in the S-E direction. Near 10.00 P.M. the minimum in the north shifts by about 42.5° towards the east and returns to 21.2°E at 11.00 P M. Finally it moves towards the north at 12.00 P.M. and remains there fixed for the remaining night. This shift of the minimum in the north coincides with the first maximum in the relative intensity found in the direction of the geographical north near 10.00 P.M. The second minimum is found near 127° in the S-E direction upto 12.00 P M. which then shifts to the south reaching 170°E to 197° (*i.e* near the geographical south) at 2.00 A M. and again returns to the previous position of 127° in the south east direction. Thus, on the average, one maximum in relative intensity is found in the south-west direction and two minima, the first deeper one in the geographical north and the second near 127°S-E direction. It appears that the result for Dumka is similar to that represented for Fritz Peak (Lat. 39.5°N) by Roach *et al* (1958). The only difference between the two results being that at Dumka (Lat. 24° 16′N) one finds minimum in the north, which Roach *et al* have not recorded for Fritz Peak observations. They have also found relatively lower value in the north but it is still higher than their minimum in the S-E direction. But at Dumka, one finds the minimum in north to be deeper than that in the south-east direction.

(2) For the diurnal variations in the relative intensity in the geographical meridian with different altitudes (zenith angles) at Dumka, one finds that the

relative intensity is minimum along the zenith direction and rises towards the horizon. The maximum has been seen to occur between (20°-50°) altitudes both in the northern and southern sides of the zenith. In the months of March and April the maximum has been almost fixed near the altitude of 20°N and 20°S. In the other months some changes in the positions of the maximum have been seen during different hours of the night. The position of minimum has remained more or less near the zenith direction. Similar variations in the relative intensity for sweeps in the geographical meridian have been shown by Dandekar & Bhonsle (1961) in their sample surveys for the measurements at Mt. Abu. Their graphs show a minimum near the zenith with increasing intensities towards the horizon and subsequently decreasing on reaching closer to the horizon. The graphs show higher intensity in the north in comparison with that in the south. However, the case at Dumka is just the reverse, where greater intensity prevails in the southern side of the zenith rather than on the northern side This difference may arise due to differences in the latitude and longitude between the two places of observation. Chamberlain (1961) has shown in his histograms that with a latitude difference of 4°, the intensity in the south may become greater than that in the north for the same zenith angle of observation, if previously the inensity in the north was greater than that in the south. That the change in longitude may give rise to the change mentioned above has been raised by Silverman (1965). Since Mt. Abu (lat. 24.6°N, long. 72.7°E) and Dumka (lat. 20°16′N, long. 84°15′E) differ more in longitude than in latitude, the difference in the results pointed out above, must have been rather due to the disparity in longitude between the two places of observation as suggested by Silverman (1965)

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